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(54) Method of transferring internet protocol packets by the use of fast ATM cell transport and network for performing the method

(57) In a method of transmitting an IP packet between a source and a destination through an ATM network which has a node formed by an ATM switch and a packet router, a reception packet or cell is transmitted to the node on an unused or undefined VC and is sent to the packet router in the node. In the packet router, an output port is selected by the use of the unused VC to establish a switched virtual channel in the ATM switch and to transfer each packet through the switched virtual channel after the switched virtual channel is established, as long as the reception packet is sent on the same VCI. Neither signaling nor protocol is needed between the nodes.

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Description

This invention relates to computer communication and networking and in particular to a method of transmitting, on an asynchronous transfer mode (ATM) network, a packet which is formed in accordance with a protocol different from that of the ATM and to a network system for transmitting the packet.

Recently, communication has widely prevailed through an internet network. This tendency seems to become more pronounced in the future. In such internet communication, an internet protocol is used to carry out data transmission. An IP (Internet Protocol) and a TCP (Transmission Control Protocol) are used for the network layer and the transport layer, respectively.

On the other hand, an asynchronous transfer mode (ATM) technique has been known as one of high performance techniques which can process a great deal of multimedia information. In such an ATM technique, all information to be transferred is arranged within a slot which has a fixed length and which is called a cell. Specifically, each cell is composed of an information field of 48 octet lengths and a header field of 5 octet lengths.

Importantly, the ATM protocol has two hiearchical layers, namely, 1) a virtual channel level and 2) a virtual path level. Herein, it is to be noted that the virtual channel is to describe a unidirectional transfer channel of an ATM cell which is specified by a common unique value of an identifier. The identifier is called a virtual channel identifier and is located within a part of the header field.

Likewise, the virtual path is to describe a unidirectional transfer path to which each virtual channel belongs and is specified by a virtual path identifier (VPI) which is also located within the header field. In this event, all of ATM cells that have the same virtual channel connection and virtual path connection (VCC/VPC) are transferred through the same route in the network. The order of the ATM cells is kept in all of the VCC. This shows that one of the ATM cells transmitted as the first transmission cell is received as a first reception cell.

On the other hand, a usual IP network is practically implemented by routers each of which is operable in response to a packet to determine an output port to which the packet is delivered. In order to determine such an output port, a great deal of processing is required in each router. This becomes a bottleneck for realizing a high speed operation in the IP network.

So as to remove such a bottleneck, consideration has been made in recent proposals about techniques which utilize a high speed transfer operation of the ATM network.

As one of such techniques, Japanese Patent Unexamined Publication No. Hei 8-125692, namely, 125692/1996 (will be called Reference 1) discloses a technique which uses a cell switch router (abbreviated to CSR). According to this technique, the CSR carries out no usual IP table look-up to detect an output port and, instead, observes a certain attribute of each IP packet to select an output port related to the attribute and to extract a VCI previously determined for the output port. Thereafter, the CSR converts the packet into a sequence of ATM cells which is headed by the determined VCI and which is transferred. Thus, the CSR can transfer the packet in a manner similar to the ATM switch.

With this structure, any operation for searching for the output port which is time-consuming is never carried out in the CSR. Accordingly, this technique enables high speed transfer operation in comparison with the conventional technique which uses a router.

Herein, it is to be noted in the above-mentioned example that conversion and transfer operation by converting a network address of an IP packet (or a packet formed in accordance with a protocol of a different layer) into a simple virtual channel may be called a cut-through or a short-cut operation hereinafter while processing for mapping an attribute of the network layer or an upper layer onto a VCI may be referred to as binding hereinafter. In addition, a mode and a path of the cut-through operation will be named a cut-through mode and a cut-through path which may be also called a switched mode and a switched path, respectively.

At any rate, when the CSR is used, the binding should be previously determined in connection with each attribute.

In order to enable the binding, ATM connection setup needs to be carried out by either a PVC (Permanent Virtual Channel) or an SVC (Switched Virtual Channel). In the other conventional techniques, such as IPOA (IP over ATM) and MPOA (Multi-Protocol over ATM), a virtual connection is also established between an original point and an end point for the cut-through operation each time when a sequence of packets is transmitted.

The conventional techniques mentioned above are disadvantageous in that the PVC basis system should prepare a great number of the VCs in dependency upon a network size and a species of attributes to be selected and, therefore, lacks scalability. On the other hand, the SVC basis system has a shortcoming that an overhead inevitably occurs on establishment of connection and brings about degradation of a merit resulting from the cut-through operation when a short session is transferred through the ATM network.

In order to solve the above-mentioned problems, WO97/28505 (referred to as Reference 2 hereinafter) discloses a method where in each node in a network is structured by an ATM switch and an IP routing module connected to the ATM switch and has a function of identifying a packet flow. In this event, each flow is usually defined by a combination of a transmission source address of an IP packet, a destination address, a port number on the TCP protocol and is used to define a sequence of packets which form a session. In addition, a flow identifier has been already defined in a new version, IP v 6, of the IP protocol.

In this method, a certain flow is at first transmitted by the use of a default VC which stands for a PVC previously defined to send the flow to the router module of the node. Such an operation itself which sends the flow to the routing module is completely identical with the operation carried out in the IP network except that the packet is transferred in the form of ATM cells. Each node monitors continuation of the flow and simultaneously carries out signaling between two adjacent ones of the nodes, namely, an upstream node and a downstream node in accordance with a local protocol which is called a flow management protocol and which is not standardized. Under the circumstances, an indication which shows assignment of a VCI to the flow is issued from the downstream node to the upstream node at a certain time instant so that a VCI is to be assigned to the flow. Responsive to this indication, the node switches the flow from the default VC to a VC indicated by the downstream node.

When similar processing is repeated in each node on a hop-by-hop basis and is completed in all of the nodes, the flow in question is transferred in the cut-through mode through the cut-through path.

In this method, each node is operated as a usual router in response to a flow which is finished within a short time and is operated by the use of an SVC in the cut-through mode in response to a flow which is continued for a comparatively long time. This method can avoid a reduction of efficiency which might occur in the conventional methods mentioned above. Herein, it is to be noted in Reference 2 that an inherent signaling protocol is run for a certain time between the nodes to establish a virtual connection while each node is operated as the router.

Although not restricted to this method, a substantial problem explicitly appears in methods of carrying out any signaling between nodes when consideration is made about a multicast operation which is very important in the IP protocol. Herein, the multicast is for simultaneously delivering a packet to a plurality of reception terminals. Such a multicast is defined by an IP multicast protocol which is known as a dense mode PIM (Protocol Independent Multicast), a DVMRP (Distance Vector Multicast Routing Protocol), and the like.

In such an existing IP protocol, each transmission node transfers a multicast packet without recognizing reception nodes. Specifically, a connection for the multicast is established in the existing IP protocol after a reception node receives a first one of packets and returns a packet which is representative of whether or not the multicast is received by the reception node itself. Herein, it is to be noted that the transmission node never acknowledges each reception node when the connection for the multicast is established.

In general, a network connection is completed when a connection request is issued from a transmission side and a reception side responds to the connection request and informs that the reception side can be connected. In other words, the network connection is completed when the transmission side acknowledges the reception side.

Taking the above into consideration, it is impossible to establish a connection for the IP multicast prior to acknowledgement of each reception node in the transmission node because each reception node is not previously known by the transmission node in the IP multicast.

In order to solve this problem, proposal has been made about a system which introduces a MARS (Multicast ATM Routing Server) as a multicast server. With this system, all of the multicasts are sent from all the transmission node to the server. The server detects each reception node related to each multicast and executes delivery of each multicast From this fact, it is readily understood that a heavy load is imposed on the server in the system and the system is therefore restricted to a network of a small size.

Moreover, a serious problem of a conventional cut-through technique is that a router mode can not be resumed once the cut-through mode is shifted from the router mode. The ATM technique is essentially introduced as novel means for operating the IP network at a high speed. However, it is not preferable that such novel means is operated in a manner different from the IP network. Practically, each conventional cut-through technique can not cope with a dynamic change which often takes place in the IP network.

The above-mentioned problems will be summarized which might occur in the conventional cut-through techniques which realize a high speed operation of a native IP network by the use of the ATM technique.

1) On the PVC base system, there is a problem in connection with scalability.
2) On the SVC base system which uses any signaling technique, it is difficult to cope with the IP multicast.
3) No way is left to return back to the router mode once the cut-through mode is driven.

It is therefore an object of this invention to provide a high speed switching method which has no defects enumerated in the above.

It is a specific object of this invention to provide a network system which is available for packet transfer using not only an internet protocol but also a protocol substantially equivalent to the internet protocol.

It is another object of this invention to provide a network system of the type described, which does not need any signaling between adjacent routers.

It is still another object of this invention to provide a high speed switching method which is applicable to an IP multicast and a mobile IP also.

It is a specific object of this invention to provide a method which is capable of transferring, at a high speed a packet which corresponds to various kinds of func-

tions required in each of the IP layers, by transferring a control packet necessary for packet transfer control after establishment of a cut-through path.

It is a yet another object of this invention to provide a network system which is identical in an ATM cell level with the other ATM networks and which is capable of carrying out both existing ATM cell exchange and fast packet transfer.

According to this invention, each node which is arranged in a network is structured by an IP routing module and an ATM switch and has a function of identifying a packet flow, like in Reference 2. However, this invention is completely different from Reference 2 in that a VC is set up by a first or an initial packet of a flow and a control packet, which is defined by an IP protocol and an upper protocol, and is sent to the routing module.

With this structure, hardware of the ATM switch is used for a high speed transport or transfer of the network but operation of the network is identical with that of a native IP network.

According to an aspect of this invention a network system is operable in response to a packet flow which defines a single session and which is formed on the basis of a predetermined protocol, to transmit the packet flow through an ATM network to a destination. The ATM network converts the packet flow into a sequence of ATM cells and comprises a source for transmitting the sequence of the ATM cells by the use of an unused VCI (Virtual Channel Identifier) and a node each of which has a plurality of input ports and a plurality of output ports. Each of the nodes comprises a router for determining one of the output ports from information included in the ATM cells that carry a first packet of the packet flow and a mechanism to associate the determined one of the output ports with the unused VCI thus setting a switched path. The node further comprises an ATM switch for transporting the remaining ATM cells except the selected one of the ATM cells through the determined one of the output ports without control of the router when each of the remaining ATM cells has a VCI identical with the unused VCI.

According to another aspect of this invention, a method is for use in transmitting a connectionless packet between a source and a destination over an ATM network comprising at least one node that includes a packet router and an ATM switch connected to the packet router. The packet router has a lookup table while the ATM switch has a plurality of input ports , a plurality of output ports, and a routing table for identifying a plurality of VCIs. The method comprises the steps of:

a) initializing the routing table in the ATM switch so that an input VCI is mapped to the packet router connected to the ATM switch;
b) transferring a packet to the packet router connected to the ATM switch when the connectionless packet is transmitted from the source to the ATM switch on an unused VC;
c) identifying one of the output ports of the ATM switch by said packet router in accordance with the above-mentioned packet and the lookup table placed in the packet router;
d) establishing a switched path in at the ATM switch by mapping the input VCI onto the one of the output ports;
e) forwarding, simultaneously with the establishing step d), the packet to a downstream ATM through the one of the output ports by the use of an unused VCI on an output side of the ATM switch; and
f) repeating the steps c) to g) on a hop-by-hop basis until a switched path is established between the source and the destination to set up a virtual path between the source and the destination so that the following connection packet is allowed to pass through the switched path.

Brief Description of the Drawing:

Figs. 1A, 1B, and 1C show a mapping state of a node for use in describing a principle of this invention;
Fig. 2 shows an example of a network which carries out operation in accordance with this invention;
Fig. 3 shows a network diagram for carrying out a part of operation according to this invention when a peek and reserve (RESERVE) protocol is applied;
Fig. 4 shows a network diagram for describing operation which is carried out after the operation illustrated in Fig. 3 is carried out;
Fig. 5 shows a diagram for use in describing a relationship between a message and a cut-through path in a method illustrated in Figs. 3 and 4;
Fig. 6 shows a network diagram for use in describing a relationship between a routed path and a cut-through path in a network which is illustrated in Figs. 4 and 8;
Fig. 7 shows a network diagram for use in describing operation which is based on an IP multicast application and which is carried out in accordance with this invention;
Fig. 8 shows a flow chart for use in describing operation carried out when the method according to this invention is applied to the DVMRP;
Fig. 9 shows a network diagram for use in describing operation carried out when the method according to this invention is applied to the RSVP; and
Fig. 10 shows a block diagram for use in describing a network system which is operable on the basis of this invention and which includes a core ATM network and edge switches.

Description of the Preferred Embodiments:

Referring to Figs. 1A through 1C, 2 and 3, description will be made as regards a principle of this invention.

Herein, features, merits, and various embodiments according to this invention will be mentioned for a better understanding of this invention.

In Figs. 1A through 1C, 2 and 3, description will be at first directed to our inventive concept and method for forwarding/routing IP packets. Herein, description is directed to establishment of a connection which is performed in this invention by the use of an ATM network. In such an ATM network, a connection is set up on an end-to-end basis and is divided into a plurality of links. In this case, each link within the connection uses a VCI peculiar to each link and each node carries out conversion between an input VCI and an output VCI. This shows that each node owns a VC space used on a downstream link.

In the case shown in Fig. 3, it is assumed that a connection is set up or established between a source node 500 and a destination node 510 through an ATM network. In this event, the ATM network has a plurality of nodes each of which comprises an ATM switch, such as 520 and 530, and an IP route, such as 525 and 535, logically coupled to the ATM switches 520 and 530. With this structure, the source node 500 carries out VC mapping for a link 505 which is directed from the source node 500 towards the ATM switch 520 while the ATM switch 520 carries out VC mapping for a link 524 which is directed from the ATM switch 520 towards the ATM switch 530.

Moreover, it is to be noted in Fig. 2 that the ATM switches 520 and 530 have ports which are connected to the individual IP routers 525the ATM switches 520 and 530 have ports which are connected to the individual IP routers 525 and 535. Herein, each of the ATM switches 520 and 530 is assumed to have a VC space which is recognizable between the ATM switches 520 and 530 and which is initially determined.

In Fig. 1A, it is surmised that each of the ATM switches has a VC routing table. In the illustrated routing table, all of unused VCs indicate switch ports which are directed to the IP router, such as 525, 535, as a destination port, when the ATM switch is initially set up, as illustrated in Fig. 1A. Herein, it is noted that the unused VCs mean VCs which are undefined on an ATM connection and which are freely used.

Next, operation of the ATM switch 520 and the IP router 525 will be described with reference to Figs. 1B and 1C. As shown in Fig. 1B, relationships between the input VCs and the output ports and between the output VCs and the output ports are stored in the ATM switch 520 and the IP router 525. Since the input VCs 3, 4, 6, and 7 are unused VCs in the example illustrated in Fig. 1B, the IP router 525 is connected to the ATM switch 520 when each of the unused VCs 3, 4, 6, and 7 is given to the ATM switch 520.

Now, let the source node 500 select the unused VC 4 for a flow A and supply the unused VC to the ATM switch 520 in the form of a sequence of ATM cells. In this event, a first group of the ATM cells that holds the unused VC containing a first packet of the flow A is delivered to the IP router 525 in accordance with the table illustrated in Fig. 1B. The IP router 525 carries out routing processing to judge that the flow A in question is to be delivered to the output port 2. In this case, the output port number in the table is rewritten into the output port 2 which corresponds to the unused VC 4, as shown in Fig. 1C. In the example illustrated in Fig. 1C, the flow A is transported or transferred to a downstream side by the use of an output VC5.

Herein, it is assumed that the source node 500 receives an IP packet of a connectionless type and selects one of the VCs as an available VC from a pool. As mentioned before, the ATM switch 520 has the VC routing table which is kept in an ATM line interface card and which is given the available VC determined for the flow. The VC routing table in the ATM switch 520 detects that the available VC given from the source node 500 is unknown in the ATM switch 520 and is detected as an unused VC.

In the meantime, the source node 500 may be an ATM switch which actually generates the flow or which may be an edge device or switch which the flow subjected to routing encounters at first.

Supplied with the unused VC through an input port of the ATM switch 520, the ATM switch 520 directs or guides the connectionless IP packet to the IP router 525 in the form of the ATM cells. In other words, the connectionless packet is routed to the IP router in response to the unused VC. Therefore, this mode will be referred to as a routed mode.

While the IP router 525 carries out processing to determine an output port of the ATM switch 520 for the connectionless IP packet, the ATM cell sequence related to the connectionless IP packet is successively stored in a buffer (Buf) and which is previously determined for the unused VC in question. Thus, a next hop is determined by the IP router 525. This shows that an output port is decided on the basis of the first packet in ATM cell forms with unused VC. In the illustrated example, the output port which is connected to the link 524 is decided by the IP router 525. In this event, a new unused VC is selected for the link 524.

After decision of the link 524, the ATM cells stored or buffered in the buffer (not shown) are redirected along with the new VC to the output port connected to the link 524.

When the new VC is an unused VC in the ATM switch 520, the ATM switch 520 at first selects the unused VC for the link 524 and rewrites the unused VC into a used VC in the VC routing table included in the input line interface card. Under the circumstances, the ATM switch 520 transfers the connectionless IP packet in the form of the ATM cell along with the unused VC towards a downstream node, namely, the ATM switch 530 and the IP router 535 which forms a next hop. The unused VC is arranged within a header field of the ATM cell.

After translation of the unused VC, the ATM switch 520 establishes a switched virtual channel (SVC) between the input port and the output port therein under control of the IP router 525 and is put into a cut-through mode, namely, a switched mode. Thereafter, the following ATM cells are transported towards the downstream node through the switched virtual channel (SVC). This shows that a next following packet of the flow in question which is received by the ATM switch 520 is not sent to the IP router 525 but is directly transferred to the downstream node in the cut-through mode. In other words, the IP router 525 is bypassed by the following IP packets in the cut-through mode.

The above-mentioned method is featured by the following respects. First, each of the flows, namely, IP flows is at first processed in the routed mode and is switched to the cut-through mode after a first one of the IP packets is processed. Second, transfer in the cut-through mode is guaranteed for the following IP packets of the same flow by using the same VC. This means that the following IP packets are not processed by the IP router located within a connection path. Third, no signaling operation is needed between adjacent ones of the nodes nor end-to-end to have the routed mode switched to the cut-through mode. Finally, it is possible to make the ATM processing based on a usual connection and the IP cut-through processing according to this invention coexist on the same ATM switch.

As mentioned before, the method according to this invention can set up a VC between the source and the destination without any signaling between nodes or ends, namely, transmission/reception between them.

However, it is to be noted that the above-mentioned method can not process any following control message by the IP router once the flow is switched to the cut-through path. This makes it difficult to return back to the routed mode after the cut-through mode is set up.

In the cut-through mode, consideration may be made about a method of utilizing a predetermined default PVC or another novel unused VC to directly transfer, to an IP router, a message (for example, a control message) which is to be processed by the IP router and which is concerned with the flow. This means that the message is not passed through the cut-through path in the cut-through mode.

Instead of utilizing the default VC or another unused VC, proposal will be made in this invention about a method of transmitting an operation administration management (OAM) cell by using an identical VC. This method is effective to transfer the control message in the cut-through mode, as will become clear later. In this case, two kinds of the OAM cells are preferably used when the control message or packet is sent during transmission of the flow. Specifically, it is preferable that a first one of the OAM cells is for allowing all of the following data cells to pass through the routed path while a second one of the OAM cells is for allowing all of the following data cells to pass through the cut-through path or for returning the same back to the cut-through path. In addition, description will be made later about necessity and a merit of sending such a control message at the beginning of, during, and at the end of the flow.

In the above description, it is assumed that the cut-through path, namely, a cut-through ATM connection is established in the same direction that the flow is transmitted and that may be referred to as a forward direction. In other words, the cut-through connection is set up at every one of the ATM switches on a hop-by-hop basis in the forward direction.

However, it is also possible to set up an ATM connection in a reverse direction at every hop by the use of a specific protocol, simultaneously with setting up the ATM connection in the forward direction.

This method will be named PRESERVE which is the abbreviation of "Peek and Reserve" standing for carrying out observation in the forward direction and reserving a connection in the reverse direction.

Referring to Figs. 4 and 5, description will be made as regards the case ere the PRESERVE protocol is applied to an application where in a source (SRC) 700 issues a transmission request to a destination server (DEST) 710 to make the destination server 710 return information back to the source (SRC).

Specifically, the request 715 is at first allowed to pass through a network from the source (SRC) 700 to the destination server (DEST) 710 via a routed path. Thereafter, a switched path 701 is established in the reverse direction by the method according to this invention which may be called IPSOFACTO, as shown in Fig. 4. In the illustrated example, the request 715 is issued from SRC 700 with an unused VC "64" indicated.

Furthermore, the ATM switches 720 and 730 which are operable as transfer switches forward the request in the forward direction by the use of VCs which correspond to the above-mentioned unused VC.

Responsive to the request, the destination server (DEST) 710 is operated to transmit a data stream in the reverse direction by the use of the VC which is identical with that attached to the request. As a result, bi-directional cut-through paths 705 and 717 are established between the SRC 700 and the DEST 710, as shown in Fig. 4, before a data stream 714 is sent from the SRC 700. Thereafter, the SRC 700 sends the data stream 714 on the identical VC "64". According to this procedure, it is possible to suppress data buffering in a switch controller to a minimum when decision is made about IP routing.

Referring to Fig. 5, a flow is processed in accordance with the above-mentioned procedure prescribed by the PRESERVE protocol in the illustrated manner and is assumed to be given in the form of a call. In this event, the SRC 700 indicates establishment or set-up of a connection between the SRC 700 and the DEST 710. Such a set-up operation is started by allowing a RESERVE message to pass through a network which is connected between the SRC 700 and the DEST 710. In

the illustrated example, three of the ATM switches are interposed between the SRC 700 and the DEST 710 and may be referred to as first, second, and third ATM switches from a nearest one of the ATM switches in the order. During passage of the RESERVE message, the RESERVE message is received at each ATM switch at a different time instant and is transferred downwards in the forward direction.

Responsive to the RESERVE message, each ATM switch sets up a cut-through path or a switched path in the reverse direction opposite to the forward direction to which the RESERVE message is transferred. The cut-through path is bi-directional and may be called a bi-directional cut-through path. As shown in Fig. 5, the cut-through path is established between the SRC 700 and the first ATM switches at a time instant t1. Likewise, the cut-through path is formed between the SRC 700 and the second ATM switch at a time instant t2 via the first ATM switch. Similar operation is carried out by all of the ATM switches interposed in the connection, until the bi-directional cut-through path is completely set up at a time instant t4. As readily understood by those skilled in the art, it is very preferable that the bi-directional cut-through path can be set up or established on the hop-by-hop basis, simultaneously with passage of the RESERVE message which may serve as a signaling message.

In such a network, it is necessary to inform or notify each ATM switch that the application of the flow is suitable for setting up the cut-through path in the reverse direction. Such information concerned with the application can be transmitted by the use of an OAM cell. The transmission of the OAM cell may be considered as a kind of control message transmission.

Referring to Fig. 6, similar operation can be also carried out in a network which includes the SRC, the DEST, and two ATM switches between the SRC and the DEST and which is also similar in structure to a network which will be illustrated later in conjunction with Fig. 8. In Fig. 6, the SRC is given a request (Req) and selects an unused VC (specified by "37" in this figure) to supply an ATM switch with an ATM cell which includes the unused VC arranged before the request. The ATM switch sends the request (Req) to an IP router when the unused VC is included in the request (Req). The ATM switch selects an output port with reference to the request (Req) and selects an unused VC (specified by "53" in this example) to send the request (Req) along with the unused VC "53" downwards. In this event, a cut-through path is formed by the use of a VC "64" between the ATM switch and the SRC. In a like manner, a routed path is formed between two adjacent ones of the IP routers due to passage of the request (Req) while a cut-through path is set up. Under the circumstances, a data stream which follows the request (Req) is bi-directionally transmitted through the cut-through path between the SRC and the DEST.

According to this invention, it is possible to set up and tear down a connection by interpreting each control packet in various kinds of the IP protocols. In order to facilitate an understanding of this invention, IP traffic used in the IP protocol will be classified into a plurality of classes and description will be made about a control operation in each class, which is carried out in accordance with this invention.

IP Traffic Classification and Control according to this invention:

1. IP traffic of a pure data stream with no signaling:

Examples of this classification are UDP (User Datagram Protocol) packets, such as ping requests/responses, IGMP(Internet Group Management Protocol) packets, or the like. Each of these packets is composed of a single packet flow and, therefore, no benefit is obtained even when a cut-through path is set up for each packet of this kind. However, no penalties are incurred, if such an IP packet is mapped onto an unused VC and the connection related to the unused VC is finished on the condition that no packet is received for a certain time.

When reusing the VC is most important like in the IGMP, a message may be transmitted on an unused VC but the unused VC may be immediately returned back to an unused VC space without identification after it is used. Such a message according to the IGMP is delivered only to an adjacent one of hops.

2. Class capable of setting a reverse path up from an IP packet by implicitly signaling:

As an example of this class, UDP-based NFS (Network File System) traffic is exemplified and is transaction oriented. In such traffic, a UDP request is sent in a forward direction while a requested datagram is sent in a reverse direction. In this case, the PRESERVE protocol may be used to set up a cut-through path in the reverse direction while a routing operation is executed as regards the forward direction.

3. Class having an explicit signaling packet:

All TCP (transmission control protocol) based traffic, such as web traffic, falls into this class. The TCP is connection oriented and has packets which are defined to explicitly carry out set-up/release of a connection and which may include a SYN packet and a FIN packet for set-up/release, SYNACK and FINACK packets defined for acknowledgement of the SYN and the FIN packets.

The method according to this invention can be realized by the use of the explicit signaling. More specifically, all the signaling packets exemplified above are passed through a routed path while the following data packets are passed through a cut-through path once a virtual channel is set up. In the case of the TCP the SYN

packet is used to set up the cut-through path while the FIN packet is used to tear down the cut-through path. In the above-mentioned method, a TCP connection can be set up or torn down in a forward direction by the use of the SYN/FIN packet sent from a sender or a source while the TCP connection can also be set up or torn down in a reverse direction by the use of the SYN-ACK/FINACK packets.

4. Class capable of sending a control packet during a session:

This class includes IP-multicast, resource reservation protocol (RSVP), mobile IP, and the like. The RSVP will be described later in detail.

In this invention, all of signaling/refreshing packets that belong to this class are transferred through a routed path while the following data packets are transferred through a cut-through path. It is noted that a virtual channel is set up by the signaling packet.

Next, description will be made about general procedure of an IP packet according to this invention, taking the above classes into consideration.

At first, a routed path is selected as an initial path by the IP packet. As a method of forming such a routed path, there are first, second, and third methods which use an unused VC, a default VC, and an ATM OAM cell, respectively. At any rate, each IP packet is checked by an IP router and is classified in the manner mentioned above. After classification, each data packet is switched to the cut-through path.

Traffic is monitored at the IP level in this invention. Specifically, the cut-through path is eliminated from a table, as shown in Fig. 1(A), when a specific protocol message, such as PRUNE, FIN, is sent on the routed path. As regards the TCP flows, a connection is set up or conversely torn down by the TCP handshake protocol (SYN, SYNACK, FIN, FINACK).

As readily understood by those skilled in the art, the method according to this invention which may be named IPSOFACTO can shorten a set-up time for the TCP traffic in comparison with the conventional techniques. Additionally, the method according to this invention allows situations to exist where a TCP session is torn down in one direction but continues in the other direction. Such situations may be called TCP half-close. This means that the method of this invention can be naturally fitted with general applications such as rsh and web browsers, such as Netscape.

Furthermore, the method, namely, IPSOFACTO according to this invention is also naturally applicable to protocols concerned with the IP-multicast and the like. This is because no specific protocol exists in this invention between nodes and the IP protocol can be executed on each ATM switch without any modification. In general, there are three common protocols for the IP multicast. They are:

1) Distance Vector Multicast Routing Protocol (DVMRP),

2) Multicast OSPF(MOSPF: Multicast Open Shortest Path First), and

3) Core-based trees (CBT).

1) The DVMRP is widely used on the worldwide multicast backbone (abbreviated to Mbone). Herein, it is to be noted that the Mbone is an experimental service and is used to develop IP multicast software and services. This experiment provides digitized audio and video applications as well as services for whiteboards, a radio channel. The Mbone uses source specific multicast trees and is closely coupled with an underlying unicast routing protocol (RIP). This method is effective when groups have dense membership and when a routing bandwidth is sufficient enough (LANs, MANs). In any event, it should be noted that multicasting is not connection oriented in the IP protocol, as mentioned before.

A multicast datagram differs from a unicast datagram in view of the fact that a group address is present within a destination address field of an IP header included in the multicast datagram. The multicasting is carried out by the use of a class D destination addressing format which may be, for example, (224.0.0.0-239.255.255.255).

2) Next, description will be directed to the MOSPF which uses a unicast routing protocol of the OSPF which defines a state of links, instead of the RIP. The MOSPF has not been widely used at the present but is hopeful in the future because it uses the underlying unicast routing protocol which is shared with a routing protocol on the ATM network, namely, the PNNI (Private Network-Network Interface).

3) The CBT uses a shared multicast tree for the group. The common root of the group is called the Rendezvous Point (RP). In the CBT, all of the multicast packets are transported as encapsulated unicast packets along the tree, independently of the underlying routing protocols. Tree nodes send explicit join messages to the RP to which a unicast address is allocated.

In the meanwhile, the Internet Engineering Task Force (IETF) has recently combined CBT and DVMRP into PIM (Protocol Independent Multicast). In the PIM, the DVMRP is used for a dense mode while the CBT is used for a sparse mode.

Taking the above into account, discussion will be made about how the IP multicast situations are varied, when the method according to this invention is used.

When the IP- multicast is implemented on the existing Ethernet, the IGMP (Internet Group Management Protocol) is run on a designated router (DR) so as to identify or recognize information for specifying a multi-

cast group to which each host or terminal belongs. In addition, the IGMP learns about group members that are directly attached to the designated router (DR).

Specifically, a query is sent to a specific group, namely, a whole host multicast group (may be, for example, (224.0.0.4)) in the form of a multicast to determine whether or not receivers for the specific multicast address group are present. Such a query is repeated at a short period of, for example, 5 seconds. Each receiver for a group (225.0.0.1) sets a local timer and the receiver whose timer is reset sends a response on 225.0.0.1 with a time to live (TTL) kept at 1. This response is received by all members of the group and also by the IP router (which monitors all multicast addresses). In the router, information related to the group member is refreshed and kept therein. If no response is received on a certain group after a certain number of cycles, the router removes the group state. Additionally, each receiver sends a join request as soon as it desires to join a group without waiting for the next query.

According to the method according to this invention, the IGMP is mapped in the following manner.

1. A query is periodically sent from the ATM switch as an ATM broadcast. Along with this query, an indication for ATM one-to-multiple mapping is transmitted to the group which is put into an active state.
2. A receiver responds to the query. If an ATM multicast channel for a specific group exists, the channel in question is used for the response. If no group specific ATM multicast channel exists, the response is sent on all the hosts.
3. When a host on the receiver side joins the group (for example, 225.0.0.1) as a member, the host picks up a random VC from its pool and sends an IGMP response which gets trapped by the switch.

The ATM broadcast and the multicast as mentioned above can be executed by the use of a function which is prepared as hardware function in the ATM switch. Herein, the mapping on the VC table will depend on the specific switch implementation. In the case where a specific ATM switch has a cell forwarding mechanism which can execute address filtering on an output side, an address is converted into a new bit map address which is afresh generated for cells of the group.

Referring to Fig. 7, an IP multicast operation will be described on the basis of this invention. The illustrated network comprises an ATM network 810 and a plurality of ATM switches (not shown) in the ATM network. The ATM network is connected to a source (SRC) 800 and a plurality of receivers (RCV) 820, 830, and 840. In the illustrated example, the multicast operation will be described among the SRC 800 and the RCVs 820, 830, and 840. Herein, it is assumed that each ATM switch can access the corresponding IP router in a manner, as mentioned before.

In the illustrated implementation, a control message, such as PRUNE, GRAFT, and JOIN, which is defined by the IP protocol and which is concerned with a connection, is transmitted on a routed path while a data stream transmitted among the SRC 800 and each RCVs 820 to 840 is transmitted on a cut-through path. This method is advantageous in that the function of the IP multicast can be simply and directly mapped onto the underlying ATM switch hardware. In this event, scalability and a dynamic flow characteristic are kept intact which are prepared for the IP multicast protocol.

Referring to Fig. 8, specific description will be made about implementation of the DVMRP protocol according to this invention. At first, a node receives a multicast packet in the form of a sequence of ATM cells (Step 900) and judges whether or not a VC is already present for transmitting the cell (Step 902) in the node. When such a VC is present in the node, the cell is transferred in a cut-through mode. On the other hand, when such a VC is not present, a packet is assembled in the node, as shown at Step 906 and is transferred to a next node (Step 908) after a one-to-many broadcast bitmap is formed in the node.

Supplied with the PRUNE message (Step 911) from a multicast group (910), the node clears, from the bitmap, a bit concerned with this group (Step 912), because the PRUNE message represents absence of a receiver.

When all the PRUNE messages are returned back to the other groups, every bit is cleared from the bitmap. This state of the bitmap reflects or specifies an actual multicast tree. When all of the bits are cleared and the bitmap is empty (Step 914), the VC in question is torn down at Step 916. Conversely, when the GRAFT message which specifies a multicast group is received by the node in question (Step 913), a bit is set in the bitmap, as shown at Step 915.

Herein, it is considered that this method according to this invention is applied to the RSVP (Resource Reservation Protocol). For a better understanding of this invention, description will be directed to the RSVP. As known in the art, the RSVP is a protocol especially designed for an integrated services internet. The RSVP enables applications to set up reservations over a network so as to respond to various kinds of requests.

Herein, it is considered that the RSVP defines a receiver-based model. In this connection, each receiver selects a resource for the reservation and starts and keeps the reservation in an active state as long as possible.

Specifically, the RSVP is an internet control protocol which is used by applications to guarantee predetermined quality of service on a network and is never a routing protocol. Therefore, the RSVP plays a role to set up and to maintain the resource reservation on a distribution tree.

A typical flow in the RSVP begins with a PATH message which is sent from a source or sender to a destina-

tion or receiver prior to transmission of a data packet stream. In the PATH message, the sender includes information related to the destination (flow spec), a traffic class, and a necessary resource (Tspec). In addition, the PATH message typically includes an Adspec field which indicates the state of congestion in each node located in a forward path, namely, an average delay over a set of time constraints.

When the PATH message arrives at the receiving node, the node compares the delay expected on that path (Adspec) with the delay requested by the application (Tspec) and then transmits a RESV message on the reverse path. Each switch in the reverse path locks in the request based upon its state. Importantly, the RSVP is a softstate protocol which is reset after lapse of a predetermined time interval and the flow should be kept by periodically producing the PATH message. Furthermore, bandwidth requests may be varied at every one of the PATH messages on the needs of the application. This way works particularly well for non-stationary sources, such as video.

It is to be noted that the RSVP flows are conveniently mapped to ATM Quality of Service (QoS) based classes. Practically, the ATM technique is one of the few technologies that allows the RSVP to request resources and then fulfill those requests. Unfortunately, the existing ATM signaling does not support bandwidth renegotiation. Consequently, the mapping from the RSVP to the ATM is not efficient because each PATH message brings about a new VC set-up which needs new signaling.

Taking the above into consideration, the RSVP is mapped onto the ATM in accordance with this invention. As mentioned before, the RSVP flow begins with the PATH message sent from a sender and may be said to be a message concerned with a connection. Responsive to the PATH message, an upstream router selects an unused VC for this flow and transmits the unused VC in the form of an OAM cell. The message is processed by an RSVP/routing module placed on an IP router port. Subsequently, the following IP packets are transported on a virtual channel for particular service classes (CBR, VBR, ABR, or UBR).

During the above operation, resources are not guaranteed. However, such a guarantee is accomplished by marking all cells with cell loss priority, namely, CLP = 1 and by making no resource reservation for the VC. Upon receipt of a corresponding RESV message in the reverse direction, the resources are locked in by invoking a connection admission control (CAC) module. All subsequent packets on that flow are sent with CLP=0 and an appropriate equivalent bandwidth is allocated for that flow.

The above-mentioned method according to this invention is advantageous in that dynamic renegotiation can be carried out for the RSVP flow without tearing down the connection or allocating a new VC.

Referring to Fig. 9, illustration is made about the RSVP implementation which carries out the above-mentioned operation in connection with a multicast flow. In Fig. 9, the sender supplies an upstream node with the PATH message prior to the following data packet. In this case, the PATH message is sent as a message which has a function of a source reservation request. In the upstream node, an ATM switch identifies the PATH message and sends the same to the RSVP/routing module which is operable as an IP router and which is connected to an IP router port. The IP router selects an unused VC and transmits the unused VC on a virtual channel in the form of an OAM cell. The OAM cell is transmitted to a downstream ATM switch which forms a downstream node. The OAM cell is sent to an IP router of the downstream node through the downstream ATM switch and the IP router selects a virtual channel on the basis of a specification requested by the PATH message. In the illustrated example, one-to-many multicast VCs is set by the IP router. The following IP packets are transmitted on cut-through paths specified by the multicast VCs.

Now, description will be directed to aggregation of flows in a core network. As readily understood by those skilled in the art, switching on a per-flow basis becomes expensive as the switching is carried out near to the core of the network. Taking this into account, it is generally desirable to switch the aggregated flows at the core of the network.

Since the method according to this invention uses a dual IP/ATM protocol stack, it is possible to execute VP-level aggregation of the flows at the core of the network by using either PVCs or SVCs on the native ATM protocol stack and to carry out the switching at every flow by the use of the method, namely, IPSOFACTO, according to this invention at the edge of the core network. In this event, a plurality of flows which pass through a cut-through path are mapped onto a route-based VC which is set up by the use of the native ATM stack.

This shows that switches located in the core of the network may only carry out switching on the basis of the VP and may not carry out switching on the per-flow basis. The job of aggregating a plurality of flows into a VP is made at the edge switch which is operated in accordance with the method of this invention. Setting up an SVC (or PVC) through the core formed by the ATM switches needs information from the IP routing module. One of the options for this is to use IP source routing at the edge of the core network and to set a SVC up for a given route. Such SVCs are torn down only when all flows on the given route are extinct.

Referring to Fig. 10, a network system carries out the aggregation of the flows in the above-mentioned manner. The illustrated network system includes a core ATM network 1401 and a plurality of ATM switches 1402, 1403, 1404, and 1405 which are arranged at a periphery of the core ATM network 1401 and which serve as edge switches mentioned above. Among others, the ATM 1405 is connected to an ATM switch 1406

on the hop-by-hop basis. When a flow is received by each edge switch, for example, the ATM switch 1405 , an SVC (VP/VC) for the flow is set up for a given route routed to the output ATM switch placed on an output side of the core ATM network 1401. Subsequently, the edge switch transfers the following flows destined to the output ATM switch, on the same VP by the use of different VCs. In the output ATM switch, the VP/VC are torn down upon reception of a final packet of a last one of the flows.

Although the IP protocol has been exemplified in the above-description, it is readily understood that the method according to this method is not restricted to the IP protocol but all of the other protocols (for example, IPX (Internet Packet Exchange) or the like) that can be handled by a routing table connected to each ATM switch. This is because the method according to this invention is non-protocol oriented.

Thus, the IP protocol or the other protocols can be naturally mapped onto each ATM switch in this invention. .This means that a fast transport function and a guarantee function of quality of services in the ATM technique can be effectively merged into a worldwide internet system in this invention. From this fact, it is to be understood that the gist of this invention is not to use each ATM switch as a switch of the ATM network on packet transfer but to use it as hardware for fast packet transport or transfer. Consequently, each switch node can execute fast packet transfer in accordance with the IP protocols without ATM signaling or without using a particular protocol locally determined between nodes, independently of the other nodes. Concurrently, each ATM switch can be also used as a native element of the ATM network on transferring an ATM cell. This is because the ATM switch is operable on the basis of the dual IP/ATM protocol stack. At any rate, it is said that the method according to this invention is very flexible and can also cope with various kinds of the protocols other than the ATM protocol.

While this invention has thus far been described in conjunction with several embodiments thereof, it will readily be possible for those skilled in the art to put this invention into practice in various other manners. For example, this invention is applicable to the shared trees, the mobile IP, and the like.

Claims

1. A network system operable in response to a packet flow which defines a single session and which is formed on the basis of a predetermined protocol, to transmit the packet flow through an ATM network to a destination, said ATM network converting the packet flow into a sequence of ATM cells and comprising:

    a source for transmitting the sequence of the ATM cells by the use of an unused VCI (Virtual Channel Identifier); and
    a node each of which has a plurality of input ports and a plurality of output ports;
    each of said nodes comprising:

        a router for determining one of the output ports from information included in the ATM cells that carry a first packet of the packet flow and a mechanism to associate the determined one of the output ports with the unused VCI thus setting a switched path; and
        an ATM switch for transporting the ATM cells through the determined one of the output ports without control of the router when each of the ATM cells has a VCI identical with the unused VCI.

2. A network system as claimed in claim 1, wherein the ATM network further comprises a downstream node which is located downwards and which sets up a VC without signaling between the node and the downstream node.

3. A network system as claimed in claim 1, where in the packet flow is given in the form of a succession of connectionless packets.

4. A network system as claimed in claim 3, wherein each of the connectionless packets is an IP (Internet Protocol) packet.

5. A network system as claimed in claim 3, wherein each of the connectionless packets is a packet selected from a group consisting of an IP packet, IPX (Internetwork Packet Exchange) protocol, and the other protocols which define properties similar to those of the IP and the IPX protocols.

6. A network system as claimed in claim 3, wherein each of the connectionless packets is packet defined by a frame relay which is a connection-oriented protocol.

7. A network system as claimed in claim 1, wherein the node sends a following router a control packet capsulated by OAM cells which are prescribed in the ATM network.

8. A method of transmitting a connectionless packet between a source and a destination over an ATM network comprising at least one node that includes a packet router and an ATM switch connected to the packet router, said packet router having a lookup table while the ATM switch has a plurality of input ports , a plurality of output ports, and a routing table for identifying a plurality of VCIs, the method comprising the steps of:

a) initializing the routing table in the ATM switch so that an input VCI is sent to the packet router connected to the ATM switch;

b) transferring a packet to the packet router connected to the ATM switch under control of the routing table of the ATM switch when the connectionless packet is transmitted from the source to the ATM switch on an unused VC;

c) identifying one of the output ports of the ATM switch by said packet router in accordance with the above-mentioned packet and the lookup table placed in the packet router;

d) establishing a switched path in at the ATM switch by mapping the input VCI onto the one of the output ports;

e) forwarding, simultaneously with the establishing step d), the packet to a downstream ATM through the one of the output ports by the use of an unused VCI on an output side of the ATM switch; and

f) repeating the steps c) to g) on a hop-by-hop basis until a switched path is established between the source and the destination to set up a virtual channel connection between the source and the destination so that the following packet flow is allowed to pass through the switched path.

9. A method as claimed in claim 8, the establishment step d) is performed by the use of a specific VC which is predetermined for transferring the connectionless packet to the packet router.

10. A method as claimed in claim 8, wherein the establishment step d) is performed by using an OAM (Operation, Administration, and Maintenance) cell which is defined on the ATM network to transfer the connectionless packet to the packet router.

11. A method as claimed in claim 8, wherein the establishment step d) is performed so that all the connectionless packets are transferred from the source to the destination through a selected one of the virtual channel and a routed path established through the packet router.

12. A method as claimed in claim 8, wherein the connectionless packet which is transferred via the packet router from the source to the destination is an OAM packet and a control packet while the connectionless packet which is transferred via the virtual channel from the source to the destination is a packet which is different from the OAM packet and the control packet.

13. A method as claimed in claim 8, wherein the establishment step d) further comprises the step of: establishing an upstream-directed switched path simultaneously with the establishment of the downstream-directed switched path so as to establish a bi-directional switched path between the node and the downstream switch.

14. A method as claimed in claim 12, wherein the establishment step d) further comprises the steps:

transferring a packet which has a function of a connection request, to a routed path formed through the packet router, in a forward direction on the hop-by-hop basis when an upper protocol concerned with the connectionless packet is connection oriented;

establishing a virtual channel from the source to the destination on the hop-by-hop basis;

transferring a packet which has a function of acknowledgement, to the routed path in a reverse direction on the hop-by-hop basis to establish a virtual path in the reverse direction.

15. A method as claimed in claim 14, wherein the establishment step d) further comprises the steps of:

transferring a finish packet which is representative of a finish of a connection and which is defined by the connection-oriented protocol, through the routed path;

tearing down the virtual channel established from the source to the destination on the hop-by-hop basis; and

transferring a packet which is representative of acknowledgement of the finish packet, from the destination to the source on the hop-by-hop basis to tear down the virtual channel in the reverse direction.

16. A method as claimed in claim 11, the connectionless packet having an upper protocol which reserves a network resource, wherein the establishment step d) comprises the steps of:

transferring, onto the routed path, a request packet which is defined by the upper protocol and which is representative of reservation of the resource; and

establishing an ATM virtual channel in response to the request packet on the hop-by-hop basis.

17. A method as claimed in claim 8, further comprising the steps of :

g) establishing a first flow with an SVC (VP/VC) in accordance with the steps a) to f) to make the first flow enter an ingress ATM switch node and to make the first flow exit from an egress

ATM switch node;

h) transporting, the following flows destined for the egress ATM switch, on the same VP by the use of different VCs; and

i) terminating the VP/VC when a final packet of a last flow by the egress ATM switch.

18. A method of transmitting a packet between a source and a plurality of destinations over an ATM network which comprises at least one node formed by an ATM switch and a packet router connected to the ATM switch, the method comprising the steps of:

    establishing a routed path on a hop-by-hop basis between the source and each destination through a set of the packet routers in the ATM network;

    establishing a switched path which corresponds to the routed path and which is formed between the source and each of the destinations through the set of the ATM switches in the ATM network:

    transferring a control packet on the routed path:

    transferring a data packet on a virtual channel and the routed path from the source when the virtual channel is established by the switched path and not, respectively, the virtual channel being established in correspondence to the routed path; and

    delivering the data packet to each of the destinations.

19. A method as claimed in claim 18, wherein the establishment step of the routed path is successively per formed at each packet router independently of the remaining packet router.

20. A method as claimed in claim 18, the switched path establishment step comprises the steps of:

    monitoring a multicast address which is included in a packet header and which is transferred through the routed path;

    judging a set of the destinations to which a multicast flow is delivered;

    forming a VC table which corresponds to the set of the destinations; and

    changing the VC table in accordance with the control packet sent through the routed path.

FIG. 1A

VP	VC	PORT
0	0	ROUTER
1	1	ROUTER
2	2	ROUTER
n	m	ROUTER

FIG. 1B

INPUT VC	PORT	OUTPUT VC
1	SIGNALING CONTROLLER	1
2	4(ATM CONNECTION 1)	6
3	ROUTER (UNUSED)	
4	ROUTER (UNUSED)	
5	3 (ATM CONNECTION 2)	4
6	ROUTER (UNUSED)	
7	ROUTER (UNUSED)	

FIG. 1C

INPUT VC	PORT	OUTPUT VC
1	SIGNALING CONTROLLER	1
2	4	6
3	ROUTER (UNUSED)	
4	2 (FLOW A)	5
5	3	4
6	ROUTER (UNUSED)	
7	ROUTER (UNUSED)	

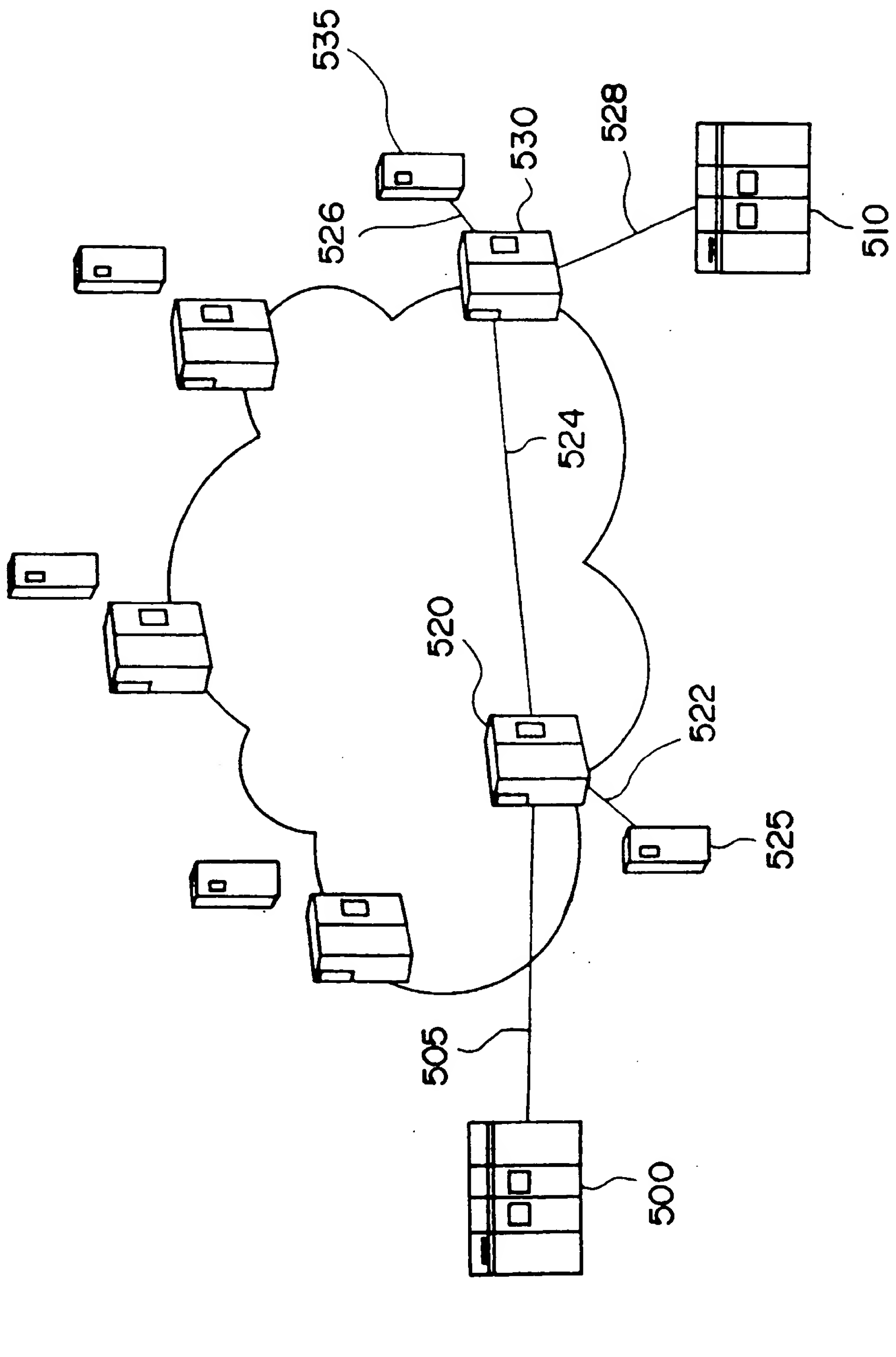


FIG. 2

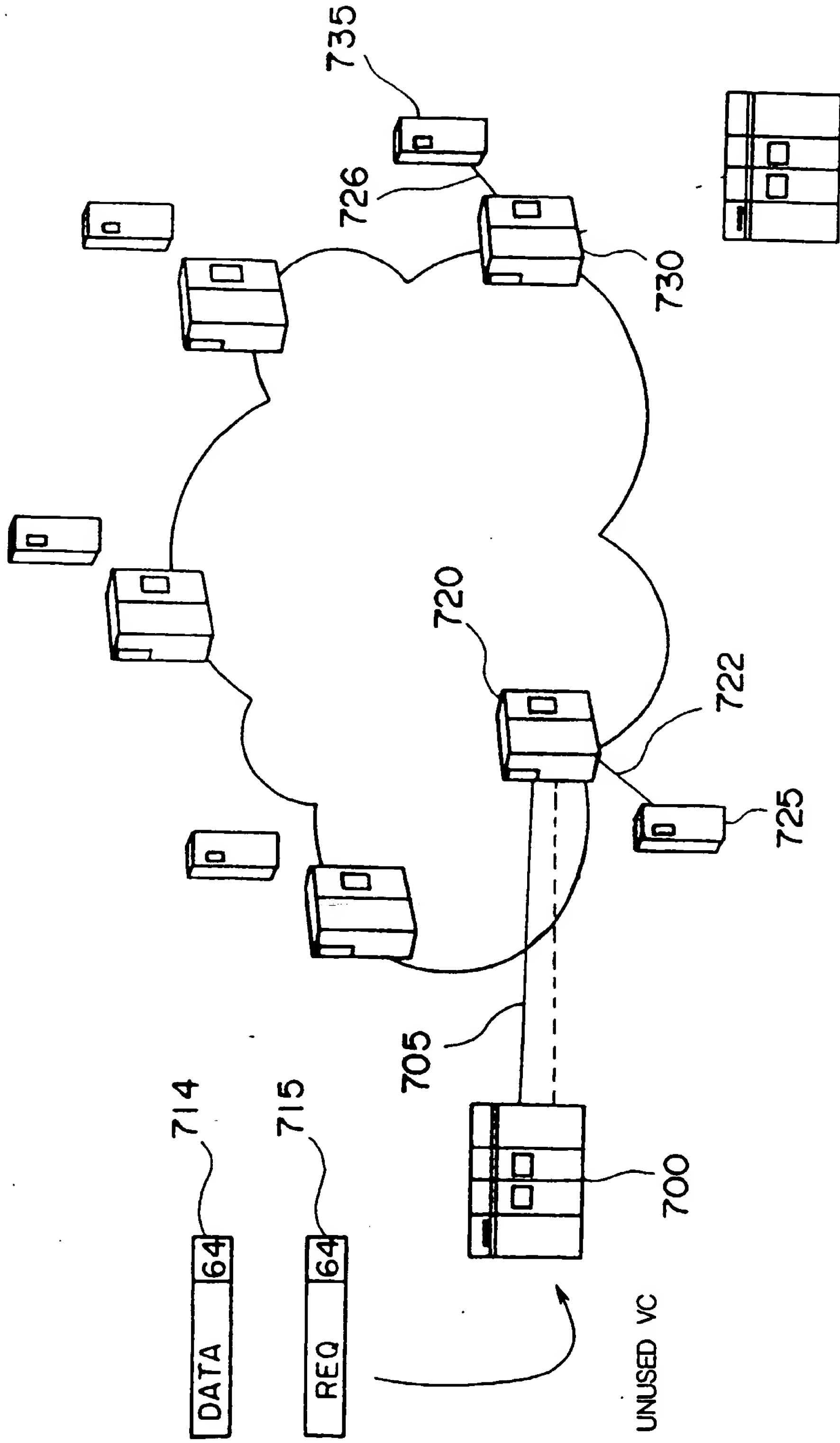

735
726
710
730
720
722
725
705
714
715
700
DATA
64
REQ
64
UNUSED VC

FIG. 3

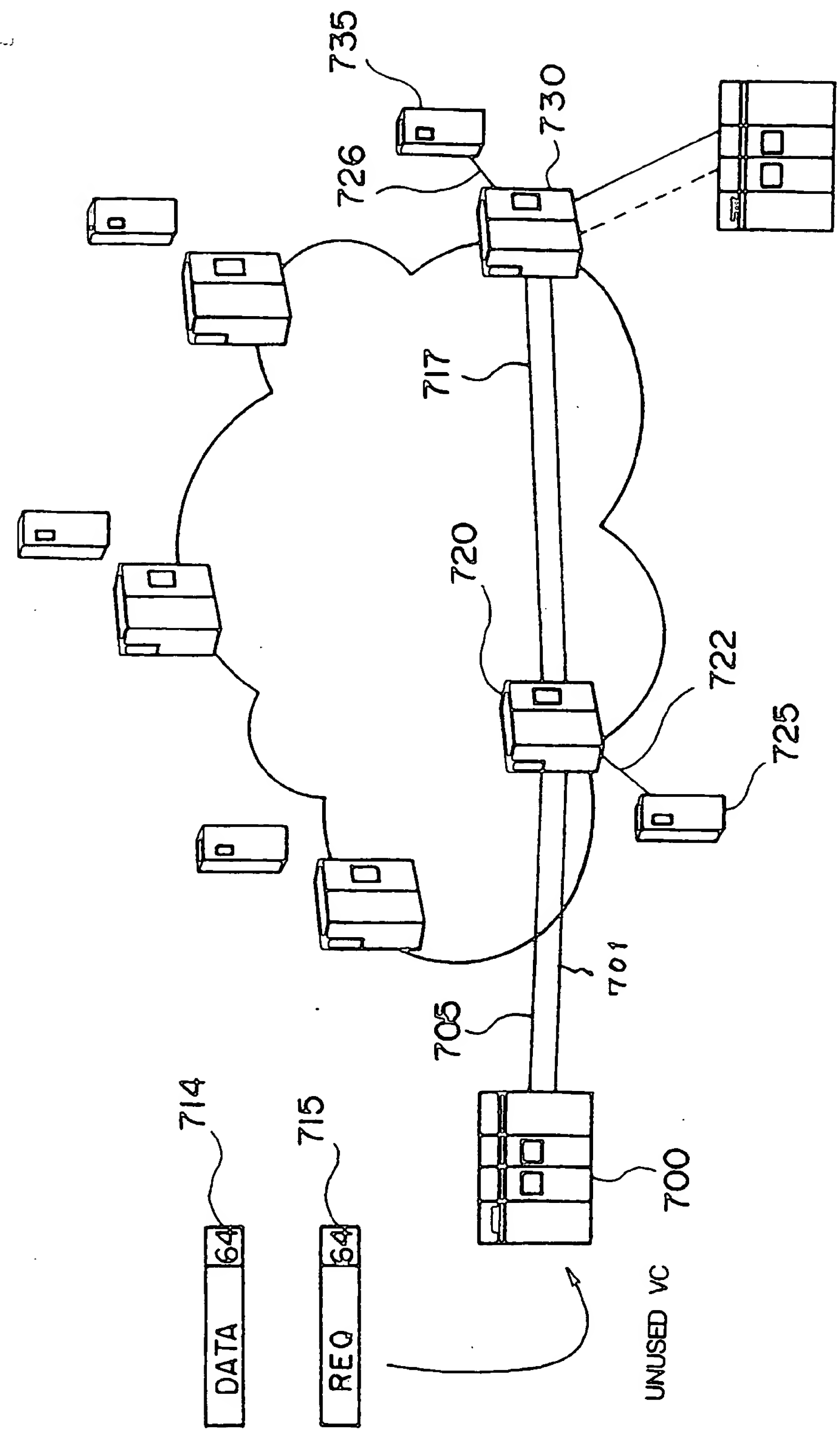

735
730
726
717
720
722
725
701
705
714
715
700
DATA
64
REQ
64
UNUSED VC

FIG. 4

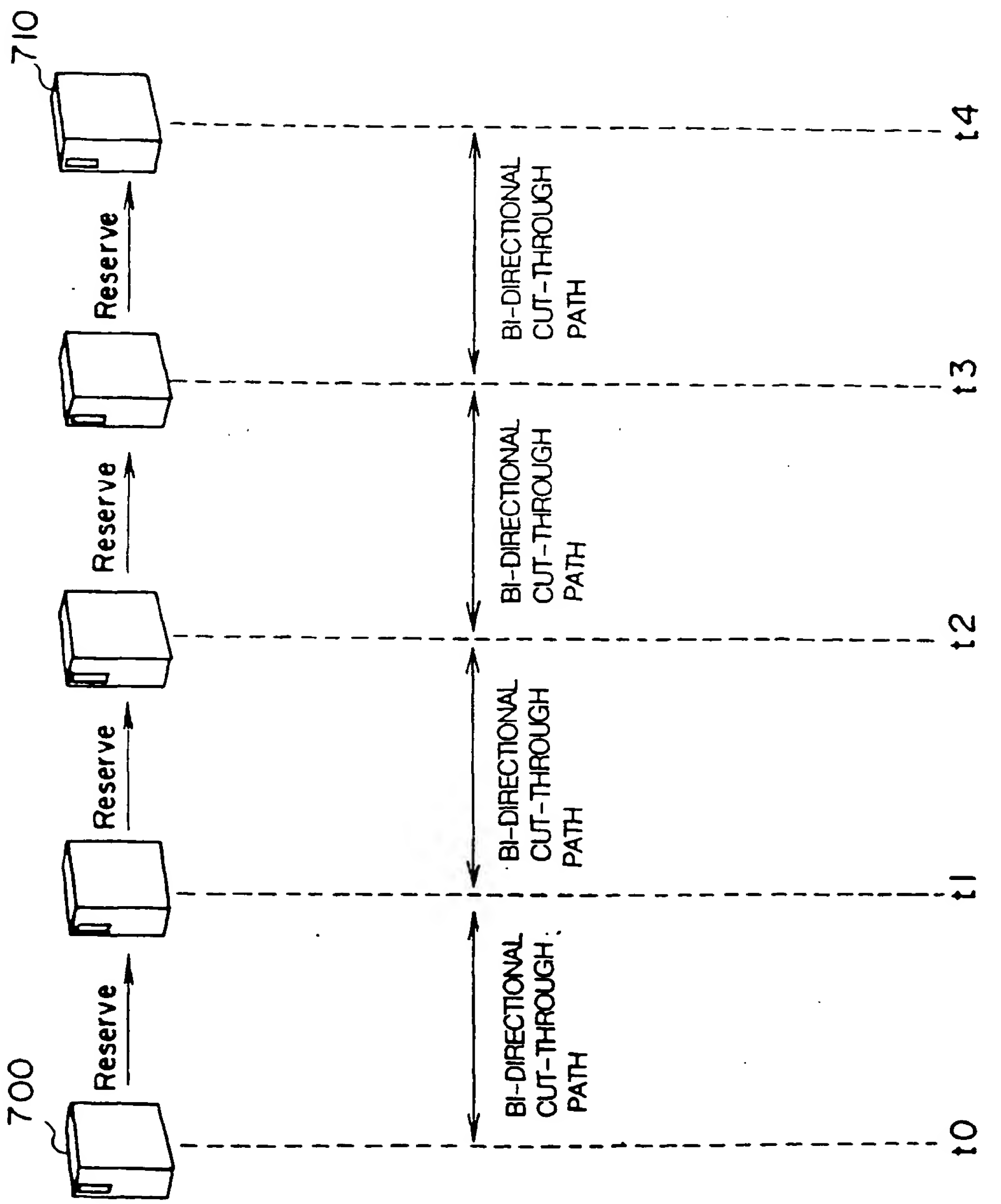
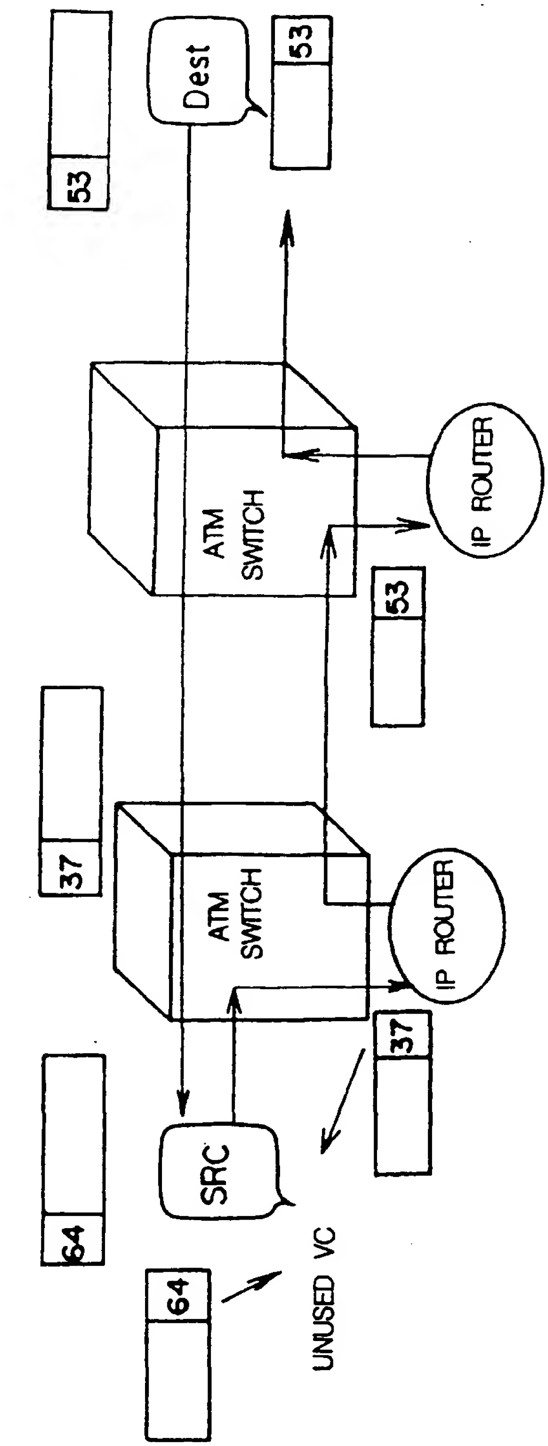

700
710
Reserve
Reserve
Reserve
Reserve
BI-DIRECTIONAL CUT-THROUGH PATH
BI-DIRECTIONAL CUT-THROUGH PATH
BI-DIRECTIONAL CUT-THROUGH PATH
BI-DIRECTIONAL CUT-THROUGH PATH
t0
t1
t2
t3
t4

FIG. 5



Dest
53
53
ATM SWITCH
IP ROUTER
53
37
ATM SWITCH
IP ROUTER
37
SRC
64
64
UNUSED VC

FIG. 6

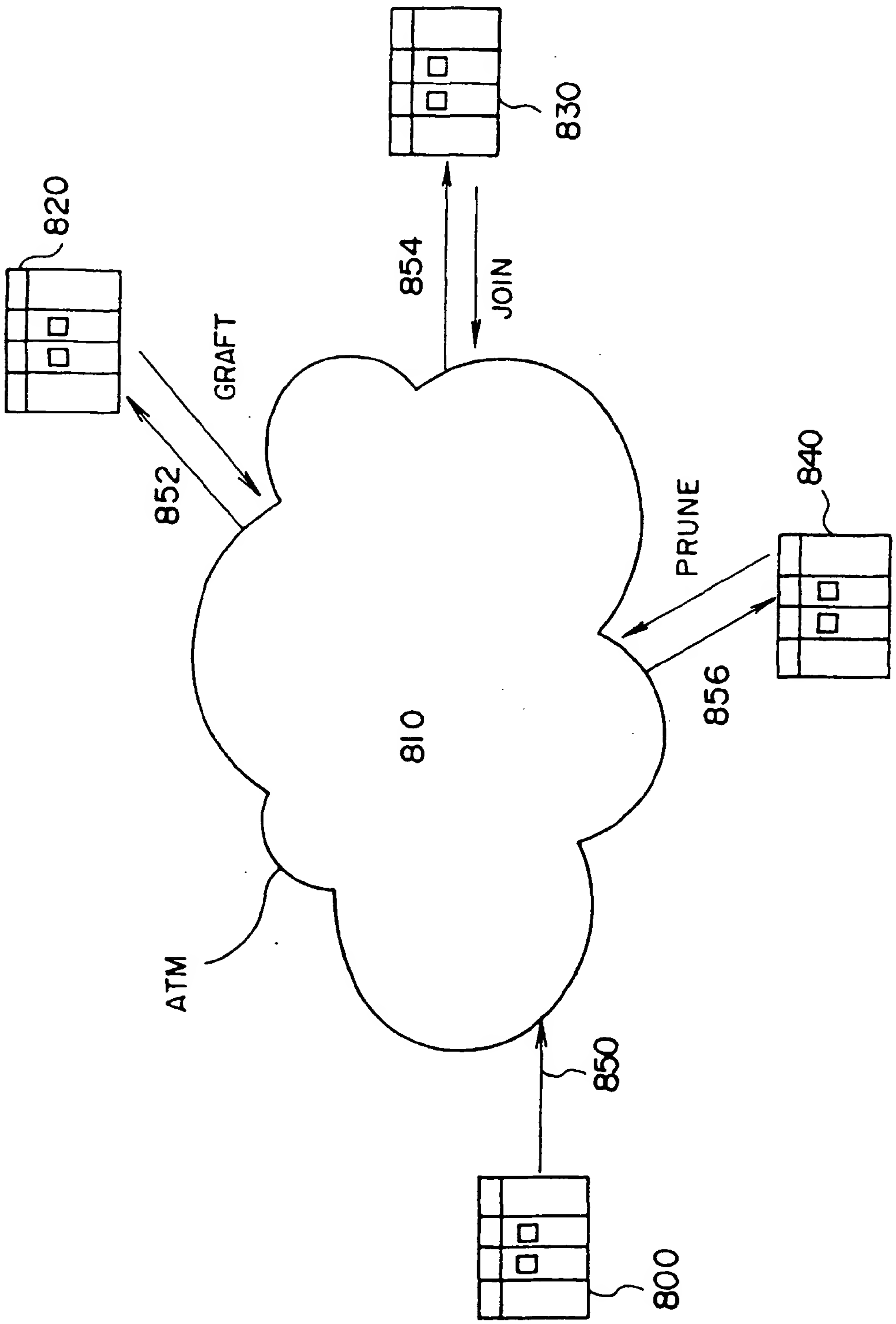


FIG. 7

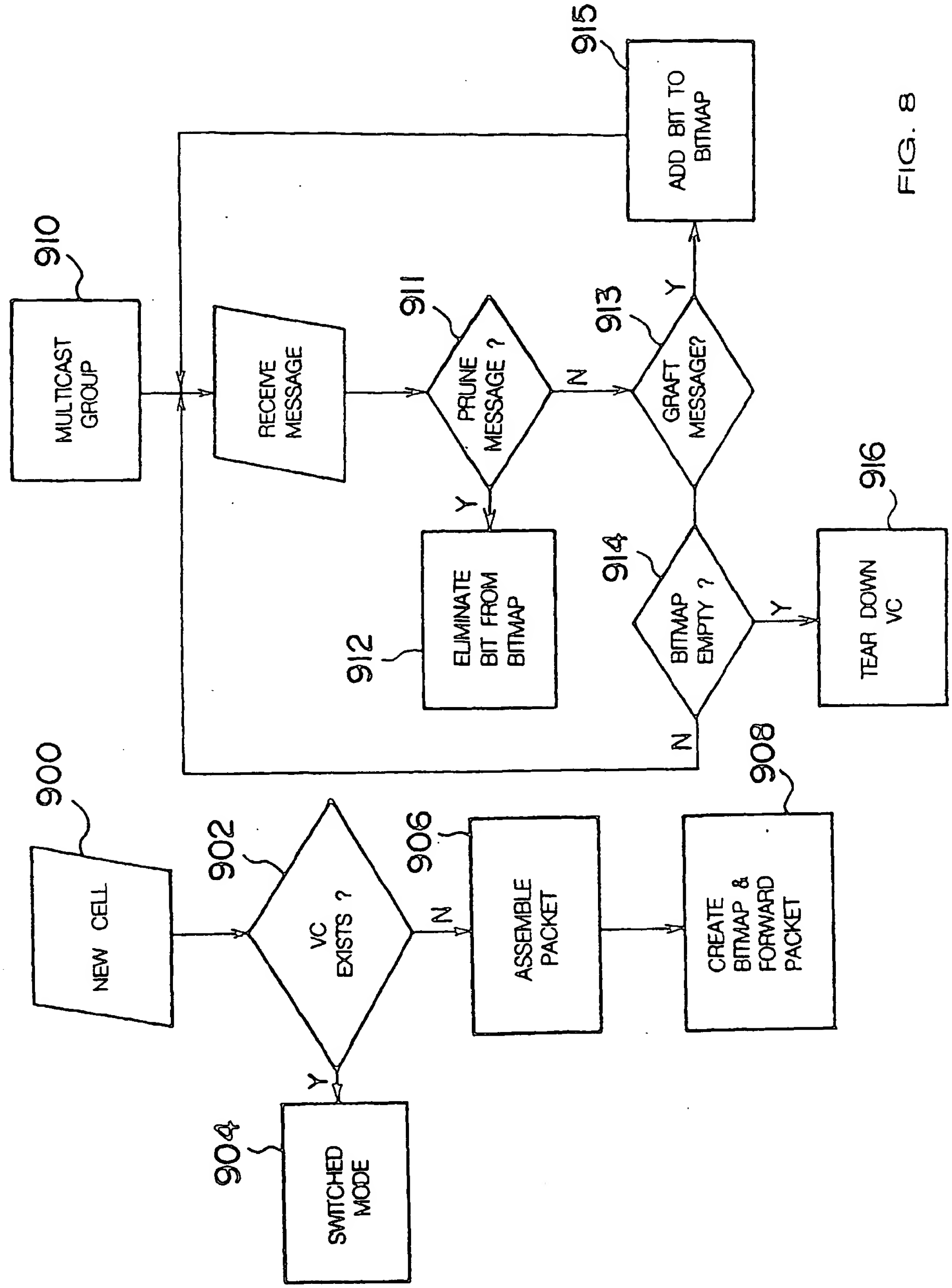

NEW CELL
900
VC EXISTS ?
902
Y
N
SWITCHED MODE
904
ASSEMBLE PACKET
906
CREATE BITMAP & FORWARD PACKET
908
MULTICAST GROUP
910
RECEIVE MESSAGE
PRUNE MESSAGE ?
911
Y
N
ELIMINATE BIT FROM BITMAP
912
GRAFT MESSAGE?
913
Y
BITMAP EMPTY ?
914
Y
N
ADD BIT TO BITMAP
915
TEAR DOWN VC
916

FIG. 8

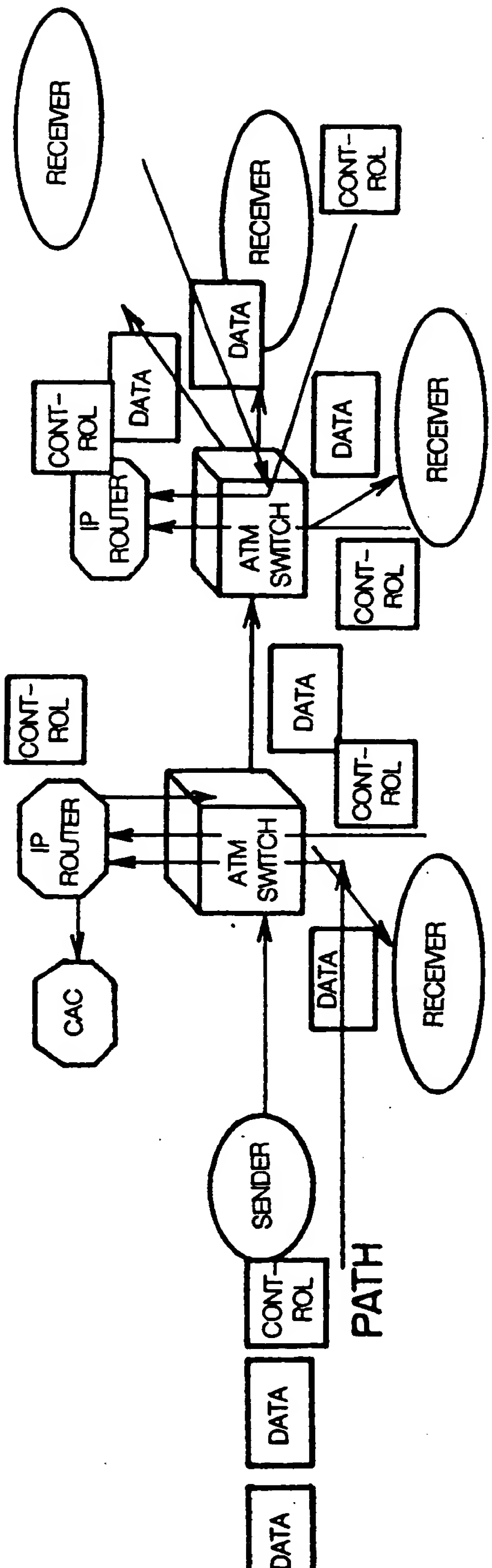

DATA
DATA
CONT-ROL
SENDER
PATH
CAC
IP ROUTER
ATM SWITCH
DATA
RECEIVER
CONT-ROL
DATA
CONT-ROL
ATM SWITCH
IP ROUTER
CONT-ROL
DATA
DATA
RECEIVER
RECEIVER
RECEIVER
CONT-ROL
CONT-ROL

FIG. 9

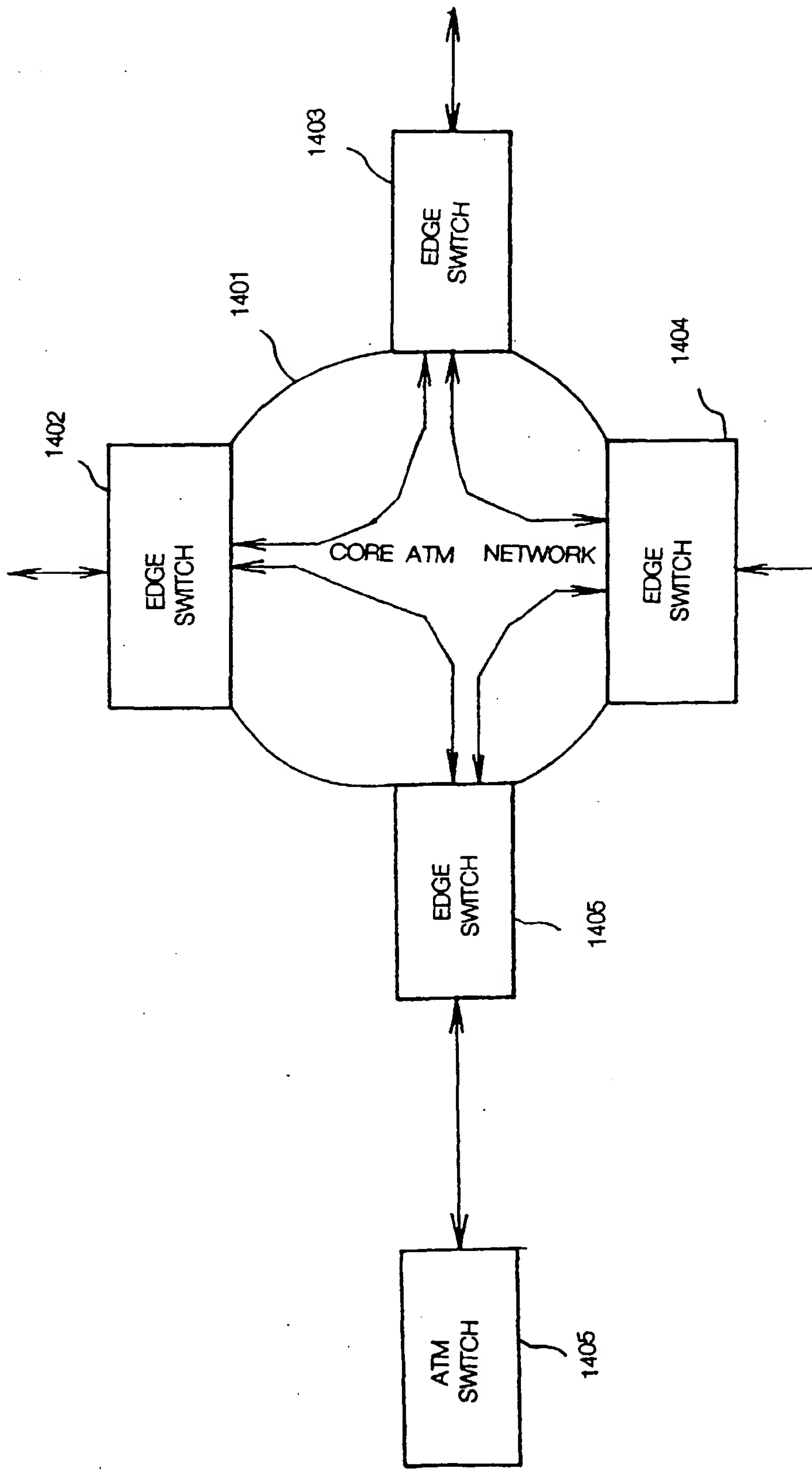

1403
EDGE SWITCH
1401
1402
EDGE SWITCH
CORE ATM NETWORK
1404
EDGE SWITCH
EDGE SWITCH
1405
ATM SWITCH
1405

FIG. 10